Claims

What is claimed is:

1. A method for the simulation of spatial visual impressions, comprising the following steps:

a) specification of the image generator geometry of an image generator, especially with regard to the structure and size of the image elements,

b) specification of the filter array geometry of a filter array, especially with regard to the structure and size of the filter elements,

c) specification of a spatial arrangement geometry in relation to the image generator and the filter array in a three-dimensional coordinate system (X,Y,Z),

d) specification of a first and a second monocular position of observation in front of the said arrangement geometry in the said three-dimensional coordinate system (X,Y,Z),

e) specification of a combined image that is suitable for display on the specified image generator geometry and that contains, in a defined assignment to the image elements, image information from different given primary images, which are identical to different views A_k (k=1..n) of a virtual or real scene or of a virtual or real object,

f) determination of a first and a second secondary image containing image elements of the specified combined image which are visible to the eye of an observer in the specified first and second monocular positions of observation on the basis of the specified filter array geometry in conjunction with the specified image generator geometry and the spatial arrangement geometry, in which an image element of a secondary image may explicitly just as well represent only part of an image element of the specified combined image, and

g) stereoscopic visualization of the first and second secondary images or parts of these secondary images as a left and right stereoscopic image, respectively.

2. A method as claimed in Claim 1, characterized in that the views A_k from which the combined image gets its image information are views of a spatial test scene, which preferably contains two to five, and even more preferably, three different graphic objects.

3. A method as claimed in Claim 2, wherein the test scene contains at least three graphic objects, characterized in that the objects within the spatial test scene are arranged in different depth positions z each, and wherein, if different views A_k are compared, preferably exactly one of the objects shows no horizontal displacement, exactly one shows a positive and exactly one shows a negative horizontal displacement.

4. A method as claimed in any one of Claims 2 or 3, characterized in that the objects imaged in the views A_k have a width of at least one full pixel column and a height of preferably at least 24 pixel rows.

5. A method as claimed in any one of Claims 2 through 4, characterized in that the objects of the test scene are homogeneously black, homogeneously gray, or structured.

6. A method as claimed in any one of Claims 2 through 5, characterized in that the objects of the test scene are arranged in front of a white or structured background.

7. A method as claimed in any one of Claims 2 through 6, characterized in that the views A_k of the test scene are recorded with virtual or real cameras, wherein the axes of the virtual or real cameras are aligned in parallel or converging, and wherein preferably the camera positions used for every two neighboring views are always spaced at approximately equal distances.

8. A method as claimed in any one of Claims 2 through 6, characterized in that the views A_k for $k>1$ are generated proceeding from view A_1 in such a way that the view A_1 is generated by means of a parallel projection of the test scene, and that, for generating the views A_k with $k>1$, each of the graphic objects of the test scene imaged in view A_1 are displaced horizontally, so that the measure of each displacement is proportional to the depth position of the respective object in the spatial test scene, and the measure of displacement selected for different views, i.e. different values of k, preferably varies.

9. A method as claimed in any one of the above Claims, characterized in that the image generator geometry specified in step a) is an orthogonal array of image

elements in rows j and columns i, wherein the image elements emit or transmit light of a specified wavelength or of a specified wavelength range, and wherein each image has an outline that can be described by a closed curve and that is preferably polygonal or, even more preferably, rectangular.

10. A method as claimed in Claim 9, characterized in that the image generator geometry is an orthogonal array of image elements in 768 rows and 3072 columns, wherein the first column emits or transmits essentially red light, the second column emits or transmits essentially green light, the third column emits or transmits essentially blue light, the fourth column again emits or transmits essentially red light, etc., and wherein each image element has an essentially rectangular outline with a height of about 300 µm and a width of about 100 µm.

11. A method as claimed in any one of the above Claims, characterized in that the filter array geometry of a filter array is specified in step b) in the form of a mask image, wherein wavelength filters and/or gray level filters β_{pq}, i.e. the filter elements of the filter array, are combined to form such a mask image in an array of rows q and columns p depending on their transmission wavelength / their transmission wavelength range / their transmittance λ_b, according the following equation:

$$b = p - d_{pq} \cdot q - n_m \cdot IntegerPart\left[\frac{p - d_{pq} \cdot q - 1}{n_m}\right]$$, in which

- p is the index of a wavelength or gray level filter β_{pq} in a row of the array,
- q is the index of a wavelength or gray level filter β_{pq} in a column of the array,
- b is an integer that specifies, for a wavelength or gray level filter β_{pq} in the position p,q, one of the intended transmission wavelengths or wavelength ranges, or a transmittance λ_b, respectively, and that can adopt values between 1 and b_{max},
- n_m is an integer greater than zero,
- d_{pq} is a selectable mask coefficient matrix for varying the generation of a mask image, and
- *IntegerPart* is a function for generating the largest integer that does not exceed the argument put in square brackets; and

in which each wavelength or gray level filter β_{pq} has an outline that can be described by a closed curve and that is preferably polygonal or, even more preferably, rectangular, and that comprises a filter area of a few 10,000 µm² up to several mm².

12. A method as claimed in Claim 11, characterized in that each wavelength or gray level filter element is approximately one third as wide as an image element and that the mask image satisfies the parameters n_m=24 and d_{pq}=-1=const, wherein $\lambda_1 .. \lambda_3$ are transmission wavelength ranges completely transparent to visible light, and $\lambda_4 .. \lambda_{24}$ are transmission wavelength ranges completely opaque to visible light.

13. A method as claimed in any one of the above Claims, characterized in that the spatial arrangement geometry specified in step c), relative to the image generator and the filter array in the said three-dimensional coordinate system (X,Y,Z), described one plane each for the image generator and the filter array, and the spatial position each of the top left and bottom right corner points of the filter array or image generator.

14. A method as claimed in Claim 13, characterized in that the unit of measurement of the said coordinate system is the millimeter, and in that the image generator plane satisfies the parameter z=0 mm, the filter array plane satisfies the condition $z \in$ [-20...+20 mm], the position of the top left corner point of the filter array or of the image generator satisfies the parameters x = y = 0 mm, and the position of the bottom right corner point of the filter array or of the image generator satisfies the parameters x = 307.2 mm and y = 230.4 mm.

15. A method as claimed in any one of the above Claims, characterized in that the combined image to be specified in step e) is generated according to the following rule:
- Partitioning the views A_k (k=1...n) each into an equal grid of rows j and columns i,
- Combining the n views A_k in rows and columns to produce a single combined image with image elements α_{ij}, with the assignment of bits of par-

tial information from the views A_k (k=1...n) to image elements α_{ij} of the positions i,j being defined by the equation

$$k = i - c_{ij} \cdot j - n \cdot IntegerPart\left[\frac{i - c_{ij} \cdot j - 1}{n}\right]$$, in which

- i is the index of an image element α_{ij} in a row of the grid,
- j is the index of an image element α_{ij} in a column of the grid,
- k is the consecutive number of the image A_k (k=1...n), from which the partial information originates that is to be rendered on a particular image element α_{ij} ,
- c_{ij} is a selectable coefficient matrix for combining or mixing on the grid the different bits of partial information originating from the images A_k (k=1...n) , and
- *IntegerPart* is a function for generating the largest integer that does not exceed the argument put in square brackets.

16. A method as claimed in any one of Claims 1 through 14, characterized in that the combined image to be specified in step e) is generated according to the following rule:
   - Partitioning the views A_k (k=1...n) each into an equal grid of rows j' and columns i', by which a tensor $A_{ki'j'}$ of order three is formed, which contains the bits of image information from views k (k=1..n) in each equal grid (i',j'),
   - Combining the bits of equal information $A_{ki'j'}$ to produce a single combined image with image elements α_{ij} in a grid (i,j), with the assignment of bits of partial information from the tensor elements $A_{ki'j'}$ (k=1...n) to image elements α_{ij} in the positions i,j of the grid (i,j) being defined by the equation

$$\alpha_{ij} = \sum_k \sum_{i'} \sum_{j'} A_{ki'j'} \cdot g_{ki'j'ij}$$, in which

   - (g) is a tensor of order five, the elements $g_{ki'j'ij}$ of which are real numbers and have the effect of weighing factors that define the weight of the respective partial information ($A_{ki'j'}$) in an image element α_{ij} , and
   - in which the grids (i,j) and (i',j') preferably have the same number of columns and the same number of rows.

17. A method as claimed in any one of the above Claims, characterized in that the determination of each of the secondary images according to step f) is performed as follows:
    - Copying the combined image (with the image elements α_{ij}) to the respective secondary image to be produced,
    - determination, for each individual image element copied in the secondary image, which area share of it is visible to the eye of an observer in the respective position of observation, allowance being made for the specified filter array geometry, the specified image generator geometry and the spatial arrangement geometry, and
    - modification (a) of the set value of each individual copied image element in the secondary image by multiplication of its original set value by the area quotient „determined visible area share of each individual copied image element in the secondary image, divided by the full area of the respective image element“ and/or
    - modification (b) of the set value of each individual copied image element in the secondary image by multiplication of its original or already modified set value by a correction factor f_k, preferably $0 \leq f_k \leq 1$, and which is a measure of the wavelength-dependent or wavelength-independent transmittance of all wavelength and/or gray level filters lying between the observer's eye in the respective position and the respective image element, or which is a measure of the wavelength-dependent or wavelength-independent transmittance of all wavelength and/or gray level filters following the respective image element seen from the respective viewing direction.

18. A method as claimed in Claim 17, characterized in that the modifications (a) and/or (b) of the set value of each individual copied image element in the secondary image, as described in detail for step f), make allowance for a function that is to be specified for a specified image generator, and that describes the functional relationship between the measurable luminance of an image element and its set value.

19. A method as claimed in any one of Claims 1 through 16, characterized in that the determination of each of the secondary images according to step f) is performed as follows:

- Area scanning of the planar component lying closest to the respective monocular position of observation according to the specified arrangement geometry, i.e. of either a filter array or the image generator, and, concurrently with the area scanning, production of a sufficiently resolved secondary image, which is an essentially correct replica of the respective visible area shares of the image elements of the combined image, or of the wavelength or gray level filters illuminated by these image elements, allowance being made for the specified filter array geometry - especially wavelength-dependent or wavelength-independent transmittances of the wavelength or gray level filters - , the specified image generator geometry, and the spatial arrangement geometry.

20. A method as claimed in Claim 19, characterized in that the determination of the secondary images described in detail for step f) makes allowance for a function that is to be specified for a specified image generator, and that describes the functional relationship between the measurable luminance of an image element and its set value.

21. A method as claimed in any one of the above Claims, characterized in that, in step g), provision is made for separate display of the secondary images to the left and the right eye, in which the secondary images are presented spatially side by side, spatially nested, or in temporal succession by means of an image generator, for example a cathode ray tube, an LC display, a DMD projector or a plasma display, and in which the display of the secondary images is particularly preferably effected by means of an image generator that has the image generator geometry specified in step a), especially with regard to the structure and size of the image elements.

22. A method as claimed in any one of the above Claims, especially as claimed in Claim 21, characterized in that, in step g), an observer is caused to have a virtual 3D impression by means of a stereoscopic visualization method that visually fuses the secondary image pair or magnified sections of it.

23. A method as claimed in any one of the above Claims, extended by a step h) that is performed after, or in parallel with, step g), and that comprises the following operation:

- Spatially staggered and/or temporally staggered comparison of the stereoscopically visualized first and second secondary images with a stereoscopically visualized image pair from the views A_k, in which preferably an image generator with approximately equal parameters each is used for the stereoscopic visualization of the first and second secondary images as well as for the stereoscopic visualization of the image pair from the views A_k, including the option that only sectional magnifications of the said images are visualized stereoscopically.

24. A method as claimed in any one of the above Claims, extended by a step i) that is performed after, or in parallel with, step g) or h), and that comprises the following operation:
    - Variation of the first and/or second position of observation in at least one of their coordinates in the coordinate system (X,Y,Z), and repeated execution of steps e) through g) or e) through h), and, optionally, any number of repetitions of the step i) described above.

25. An arrangement for implementing the method of simulating spatial visual impressions as claimed in Claim 1, comprising:

a) Means for the digital specification of the image generator geometry of an image generator, especially with regard to the structure and size of the image elements,

b) Means for the digital specification of the filter array geometry of a filter array, especially with regard to the structure and size of the filter elements,

c) Means for the digital specification of a spatial arrangement geometry in relation to the image generator and the filter array in a three-dimensional coordinate system (X,Y,Z),

d) Means for the digital specification of a first and a second monocular position of observation in front of the said arrangement geometry in the said three-dimensional coordinate system (X,Y,Z),

e) Means for the specification of a combined image, which is suitable for display on the specified image generator geometry, and which, in a defined assignment to the image elements, contains bits of image information from different given primary images, which are identical to different views A_k ($k=1..n$) of a virtual or real scene, or of a virtual or real object,

f) Means for the determination of a first and a second secondary image, which contains those image elements of the specified combined image that are visible to an observer's eye in the respective specified first and second monocular position of observation due to the specified filter array geometry in conjunction with the specified image generator geometry and the spatial arrangement geometry, including the explicit option that one image element of a secondary image may represent only a part of an image element of the specified combined image, and

g) Means for the stereoscopic visualization of the first and second secondary images or parts of these secondary images as a left and right stereoscopic image, respectively.

26. An arrangement as claimed in Claim 25, characterized in that the means a) through f) are contained in a common unit configured as a software-controlled PC, and in that the means g) comprise a stereoscope, or shutter glasses and a monitor.

[Translation of the legends in Fig. 12:]

Leuchtdichte vs. Einstellwert	Luminance vs. set value
(roter Wellenlängenbereich)	(red wavelength range)
(grüner Wellenlängenbereich)	(green wavelength range)
(blauer Wellenlängenbereich)	(blue wavelength range)
Leuchtdichte [cd/m²]	Luminance [cd/m²]
Einstellwert (0..255)	Set value (0...255)

[END OF TRANSLATION]

Hereby I certify that the foregoing text is a faithful and complete translation of an original German patent application, which was put before me today and a copy of which is affixed to the translation.

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Appointed by the President of the Gera Regional Court as Authorized Translator of English for the Courts and Notaries of Thuringia